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Process for Monitoring Function of an NO_X Sensor Arranged in an Exhaust Duct of an Internal Combustion Engine

The invention relates to a process for monitoring the function of an NOx sensor arranged in an exhaust duct of an internal combustion engine, having the features named in the generic clause of Claim 1.

For reduction of a pollution emission of internal combustion engines, a known practice is to arrange suitable catalysts in the exhaust gas duct. In the catalysts, firstly, pollutants that can act as reducing agents, such as CO, HC or H_2, may be oxidized by atmospheric oxygen, and secondly, NOx formed during a process of combustion in the engine may likewise be reduced to nitrogen on the catalysts with the aid of the reducing agents.

If the engine is in a lean mode more favorable to combustion, the proportion of oxygen in the air-fuel mixture is increased, and consequently a proportion of the reducing agents in the exhaust is decreased. In that case, of course, an adequate reaction of NOx is no longer ensured. As a remedy, an NOx reservoir is arranged in the exhaust duct, and it may be combined with the

catalysts to make an NOx storage catalyst. The NOx storage catalyst will absorb NOx either so long as an NOx desorption temperature is exceeded or until an NOx storage capacity is exhausted. Prior to that time, then, a change must take place into a regeneration mode with 1 to regenerate the NOx storage catalyst and prevent NOx emission.

It is known that a necessity of regeneration may be made dependent on an NOx concentration detected downstream from the NOx storage catalyst. The NOx concentration is detected by means of an NOx sensor. A disadvantage of this, however, is that in the presence of a misfunction of the NOx sensor, too high NOx emissions may occur, or an unnecessary added consumption may result from a premature regenerating measure.

The object of the invention is to detect such misfunctions of the NOx sensor in simple manner so that appropriate countermeasures may then be adopted if necessary.

According to the invention, this object is accomplished by the process for monitoring the functioning of the NOx sensor, having the features named in Claims 1 and 5. By

(a) Determining an NOx mass absorbed by the NOx storage catalyst from a test signal of the NOx sensor within a period of diagnosis,

(b) At the same time, in terms of a model of the NOx storage catalyst, calculating an absorbed NOx mass target, and

(c) Comparing a ratio of the NOx mass to the NOx mass target (control value KW_n) with a lower bound G_{nu} or an upper bound G_{no},

or by

(a) Detecting a duration t_{mes} for a complete NOx regeneration of the Nox storage catalyst,

(b) From a model of the NOx storage catalyst and a measured or calculated NOx loading condition, calculating a target duration t_{mod} for the NOx regeneration, and

(c) Comparing a ratio of the duration t_{mes} to the target duration t_{mod} (control value KW_t) with a lower bound G_{tw} or an upper bound G_{to},

the monitoring of the function of the NOx sensor can be accomplished in simple manner.

In a preferred embodiment of the process, upon transgression of the control value KWn or KWt, respectively, beyond the upper bounds G_{no}, G_{to}, or upon transgression of the lower bounds G_{nu}, G_{tu}, maintenance signals are generated. Then after occurrence of such a maintenance signal, the error can be corrected by suitable maintenance measures, or the NOx sensor can be replaced if necessary.

Further, it is advantageous to set the period of diagnosis to begin immediately after a complete NOx regeneration of the NOx storage catalyst and a change in the lean mode of the engine. Advantageously, the period of diagnosis will end after identification of a need to regenerate the NOx storage catalyst or upon a change in regeneration mode.

Monitoring of the function of the NOx sensor should preferably take place only when a very largely constant lean mode of operation of the engine has been

detected. In this way, the influences, difficult to allow for, of a dynamic operation of the engine, on the model of the storage catalyst, can be avoided.

Other preferred embodiments of the invention are given by the features named in the subsidiary claims.

The invention will now be illustrated in more detail in terms of an example with reference to the accompanying drawings, in which

Fig. 1 shows a schematic arrangement of an internal combustion engine having an NOx storage catalyst and an NOx sensor, and

Fig. 2 shows a block diagram of a monitoring of the function of the NOx sensor according to the example.

Fig. 1 shows an arrangement of an internal combustion engine 10 comprising, in an exhaust duct 12, a precatalyst 14 and an NOx storage catalyst 16. The precatalyst 14 and the NOx storage catalyst 16 serve to diminish a pollutant emission of the engine 10.

Ordinarily, the catalyst 14, 16 comprise components that make possible an oxidation of reducing agents formed, such as CO, HC or H_2, by atmospheric oxygen. At least the NO_x storage catalyst 16 comprises a catalyst component that makes possible a reduction of NO_x likewise formed during a process of combustion of an air-fuel mixture, by means of the reducing agents. To be sure, if the engine 10 is in a lean mode, as a rule a proportion of the reducing agents in the exhaust will not suffice to afford a sufficiently high conversion of NO_x. In lean mode, therefore, the NO_x is absorbed as nitrate by a storage component of the NO_x storage catalyst 16.

The absorption of the NO_x can take place only until either an NO_x desorption temperature is exceeded or an NO_x storage capacity is exhausted. Before this point in time, therefore, a change must take place into a regeneration mode with $\lambda \leq 1$ to make possible an NO_x regeneration. In known manner, an NO_x concentration or emission detected by the NO_x sensor 18 may be the criterion for a need to regenerate. A corresponding test signal is passed on for example to an engine control instrument 20, is evaluated there, and used to control an operating mode of the engine 10.

Fig. 2 shows a block diagram with which a monitoring of the function of the NO_x sensor 18 during dynamic operation of the engine 10 can take place according to this example. In a step S1, it is first detected whether a complete NO_x regeneration of the NO_x storage catalyst 16 has been carried out. If this is not the case, then the monitoring of the function of the sensor 18 is discontinued (step S2).

At the beginning of the lean mode (step S3), a determination of an NO_x mass incorporated in the NO_x storage catalyst 16 is started. For this period, firstly the NO_x concentration downstream from the NO_x storage catalyst 16 is detected by the NO_x sensor during a preassigned period of diagnosis and accumulated, and then deducted from a measured or calculated crude NO_x emission of the engine 10. Secondly, with the aid of known models of the NO_x storage catalyst 16, and from the crude NO_x emission, a target mass of absorbed NO_x is calculated. The target NO_x mass corresponds maximally to an NO_x mass that can be absorbed by a fresh NO_x storage catalyst 16.

In a step S4, it is checked continuously whether the engine 10 is in constant lean operation during the period of diagnosis. In the case of disturbances due to dynamic processes, for example a change in a homogeneous mode or an abrupt shutdown, the target NO_x mass calculated for the period of diagnosis is especially prone to error, and therefore the monitoring of function is broken off (step S5). Preferably, the period of diagnosis is so determined that it – as already explained – begins with the change in the lean mode (step S3) and continues until a need for regeneration is detected (step S6).

Such a need for regeneration may for example be detected by way of the NO_x sensor 18 in the form of a threshold emission for NO_x. Once the need for regeneration is present, a change into the regeneration mode with $\lambda \leq 1$ is initiated (step S7). Simultaneously, a time counter is started, to determine a duration t_{mes} for a complete NO_x regeneration.

From a ratio of the absorbed NO_x mass found by way of the NO_x sensor 18 for the NO_x storage catalyst 18 and the target NO_x mass, a control value KW_n is formed in a step S8. If the control value KW_n, in a step S9, transgresses an upper bound G_{no} or a lower bound G_{nu}, then there is a defect in the NO_x sensor 18, and a maintenance signal is produced (step S10). The upper bound GW_o is usually so chosen that it reflects a ratio of the NO_x mass found by way of the NO_x sensor 18 to the target NO_x mass in a fresh NO_x storage catalyst 16.

If the control value KW_n lies between the two bounds G_{nu}, G_{no}, then in a step S11 it can be checked whether the NO_x regeneration has been carried out completely. For this purpose for example a lambda probe 22 is suitable,

arranged downstream from the NO_x storage catalyst 16. Towards the end of the NO_x regeneration, the value of lambda declines distinctly, and for example by preassignment of a suitable threshold value, a stop signal can be set for the time counter (step S13). If the NO_x regeneration is discontinued prematurely, the functional monitoring of the NO_x sensor 18 is broken off here (step S12).

With the aid of the model of the storage catalyst, a target duration t_{mod} for the NO_x regeneration is calculated from a measured or calculated state of NO_x loading. A ratio of the duration t_{mes} to the target duration t_{mod} yields a control value KW_t (step S14). The control value KW_t is compared with an upper bound G_{to} or a lower bound G_{tu} in a step S15. If the control value KW_t transgresses the upper bound G_{to} or the lower bound G_{tu}, there is a sensor defect, and a maintenance signal is produced (step S16). If this is not the case, then a new cycle of functional monitoring, beginning with step S3, may be introduced. The upper bound G_{to} is again so chosen that it reflects a ratio of the duration t_{mes} to the target duration t_{mod} in a fresh NO_x storage catalyst 16.

Also, sensor plausibility is checked as to whether it does not merely yield a lesser measures fill, for example with poorer storage behavior of the catalyst, or whether at the same time, the measured regeneration time required is reduced to a corresponding extent.